(12) UK Patent Application (19) GB (11) 2 335 242 (13) A

(43) Date of A Publication 15.09.1999

(21) Application No 9904382.0

(22) Date of Filing 25.02.1999

(30) Priority Data
(31) 10105298 (32) 12.03.1998 (33) JP

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(51) INT CL$^6$
F16C 32/04

(52) UK CL (Edition Q )
F2A AD36 A16
U1S S1917 S1984 S2006

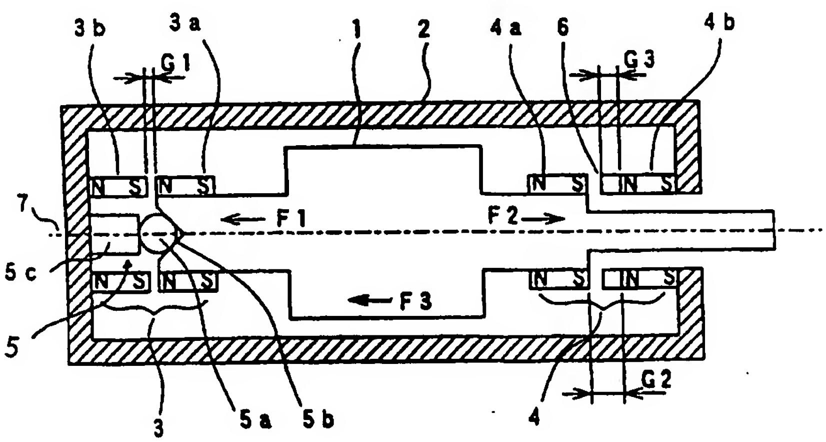
(56) Documents Cited
GB 2134991 A GB 1481658 A GB 0739979 A

(58) Field of Search
UK CL (Edition Q ) F2A AD10 AD14 AD16 AD18 AD19 AD36
INT CL$^6$ F16C 39/06
Online: EPODOC, JAPIO, WPI

(54) Abstract Title
**Rotor support with one or two pairs of permanent magnetic bearings and a pivot**

(57) A bearing structure has one or two (figs 2, 5) pairs of axially spaced permanent magnetic bearings 3, 4 for radially supporting a rotor 1 at two supporting points in a non-contact manner. Thrust forces F1, F2 of each magnetic bearing in a pair act in opposite axial directions and a pivot 5a on an axis 7 of the rotor 1 bears a shaft end 5b of the rotor 1 when the shaft end 5b is displaced in an axial direction from the neutral position where all thrust forces acting on the rotor balance. The magnetic bearings 3, 4 may attract or repel (figs 4-6) and be orientated axially or radially (figs 4-6) of the rotor 1. To cope with excessive rotor displacements in both axial directions, a further stop 6 (8 fig 4) or second pivot (figs 7, 8) may be used. Stop 6 may also space the magnets 4a, 4b to prevent sticking. Two pairs of magnetic bearings may be concentric (fig 2). The rotor may be for a motor, fan or polygonal mirror.

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig. 1

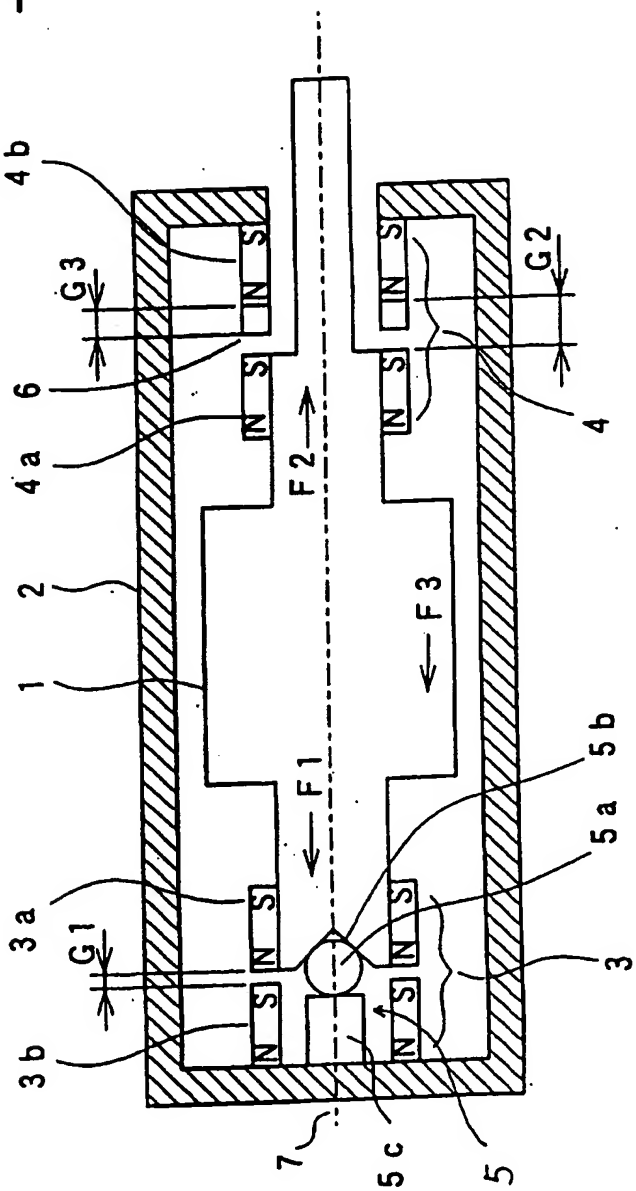


Fig. 2

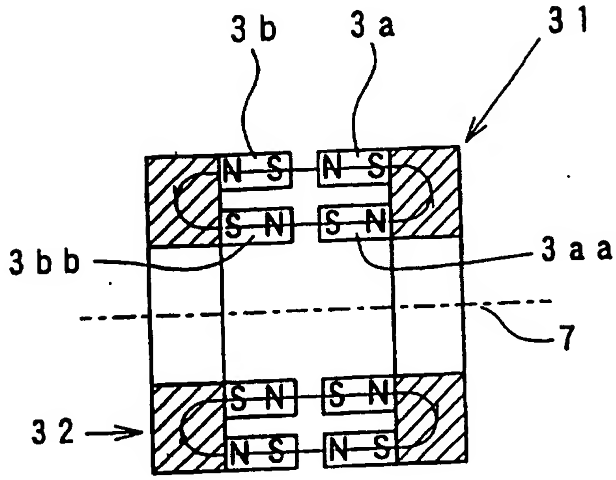



Fig. 3

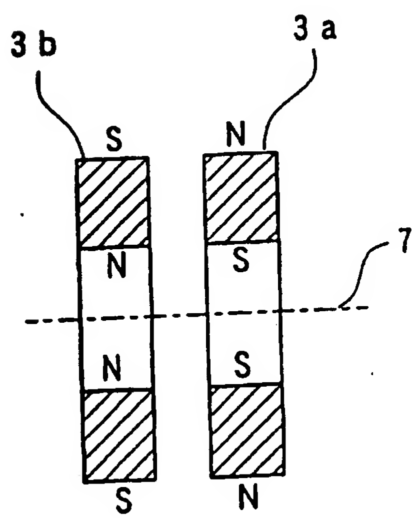


Fig. 4

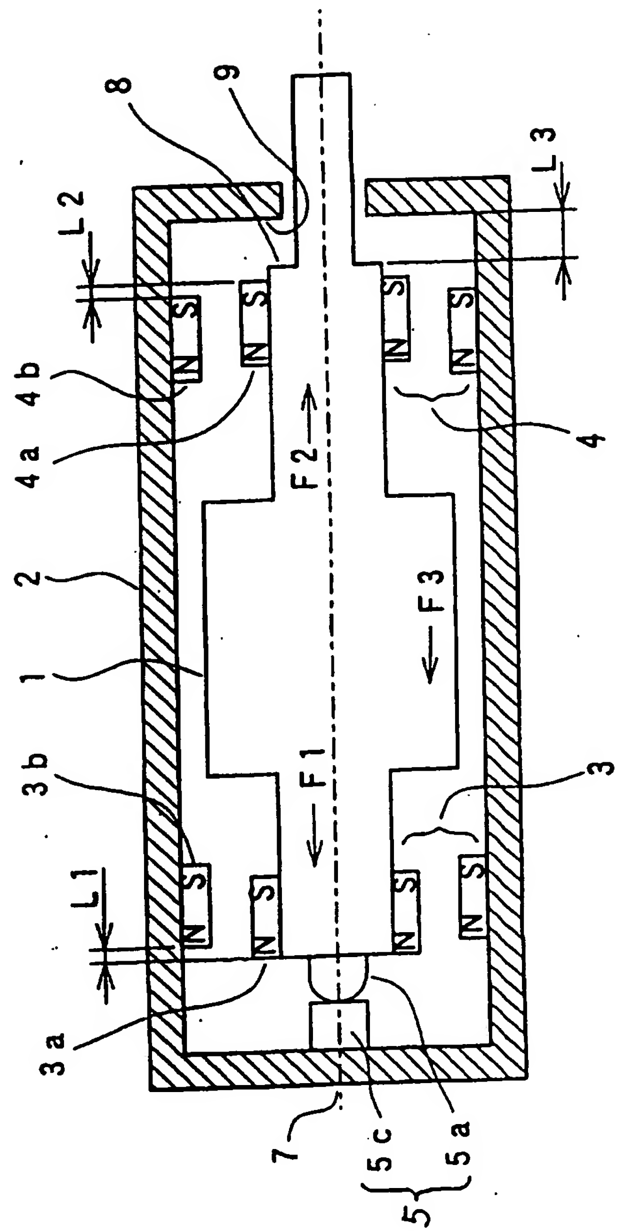


Fig. 5

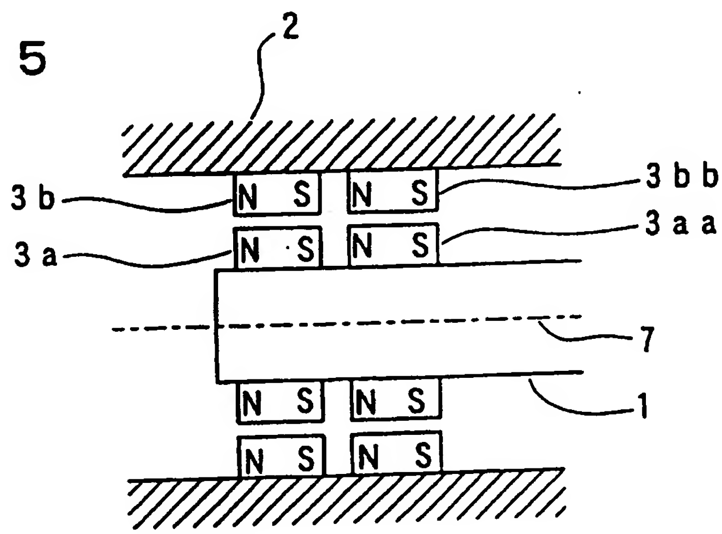



Fig. 6

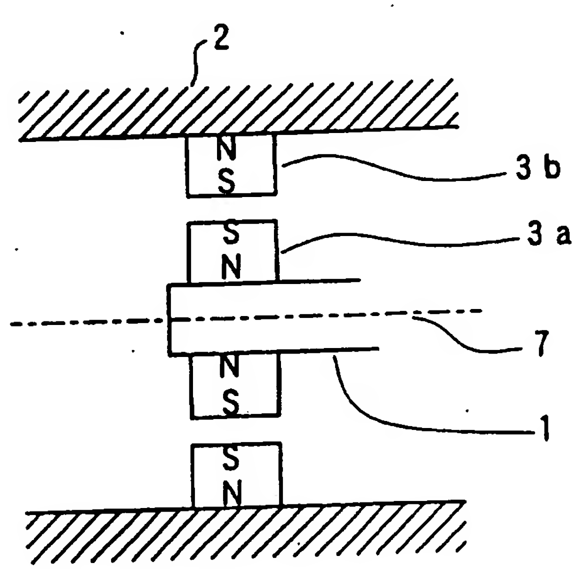


Fig. 7

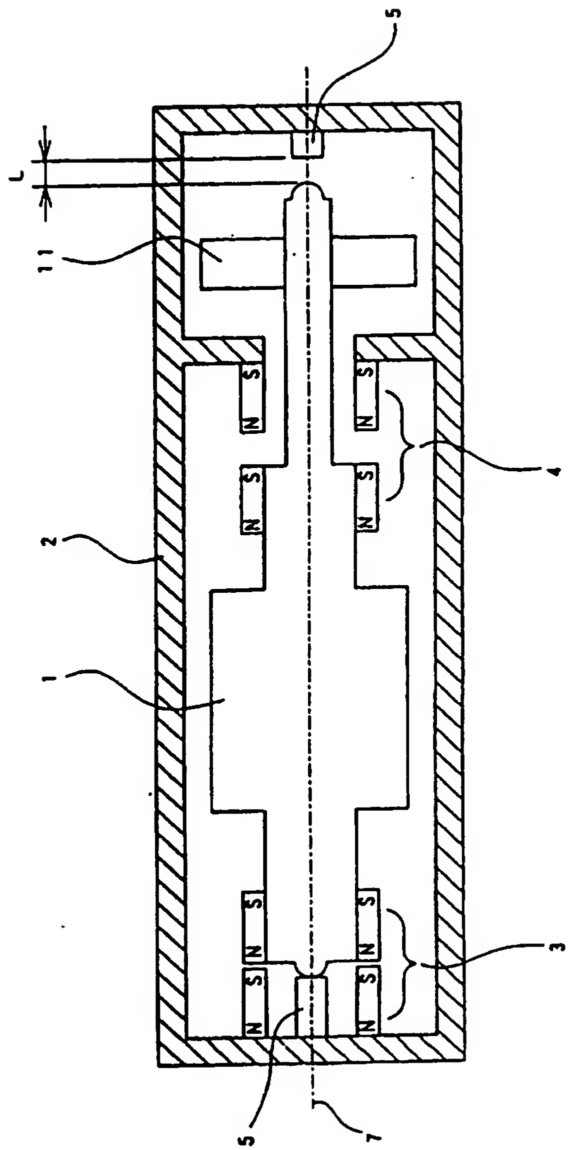
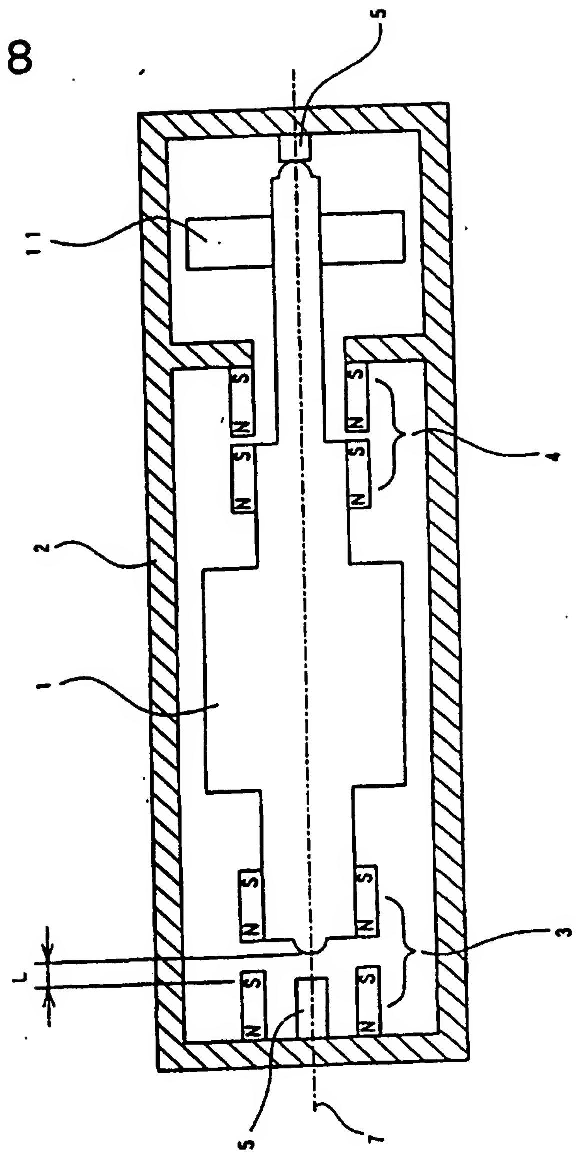


Fig. 8



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# BEARING STRUCTURE

## BACKGROUND OF THE INVENTION

The present invention relates to a bearing structure for a rotating device such as motors and the like, by which low noise and long service life can be provided at low cost over a range from low speed rotation to super high speed rotation, and, more particularly, to a bearing structure for small-sized devices such as high speed fan motors, scanner motors and the like, for which low noise, long service life and high reliability are demanded.

Air dynamic pressure bearings and magnetic bearings have been put to practical use as non-contact type bearings for supporting a high-speed rotating shaft. The former provides supporting in a radial direction with air pressure existent between a shaft and a sleeve, but behaves in a low rotational speed range in the same manner as a contact type bearing does, leaving a problem that abrasion occurs every start and stop. On the other hand, magnetic bearings are constructed to provide supporting in a radial direction or in an axial direction by the use of attracting forces or repulsive forces of magnets.

However, radial magnetic bearings constructed to obtain a centripetal force by the use of repulsive forces of magnets will simultaneously generate eccentric forces in an axial direction, and axial magnetic bearings constructed to support axial load by the use of attracting forces or repulsive forces of magnets will simultaneously generate eccentric forces in a radial direction. Therefore, it is difficult to provide supporting simultaneously in both radial and axial directions with a combination of only

permanent magnets, and so it is necessary to perform exciting control using an electromagnet for either of radial and axial directions, thus presenting a problem of complexed structure and high cost.

## SUMMARY OF THE INVENTION

The object of the present invention is to provide a bearing structure which realizes a bearing of low noise, long service life and high reliability even at high speeds at low cost.

To solve the above problem and attain the above object, the bearing structure bears a radial load on a rotor through one or two sets of radial magnetic bearings, cancels forces generated by the magnetic bearings in an axial direction one another, or cancels such forces including forces exerted from outside in the axial direction.

A bearing structure according to the present invention comprises one or two sets of magnetic bearings for radially supporting a rotor of a rotating device at two supporting points in non-contact manner with magnetic forces, the magnetic bearings being arranged such that thrust forces act in opposite axial directions, and a pivot disposed on an axis of the rotor for bearing a shaft end of the rotor at a point while displacing the shaft end in an axial direction from a neutral position where all thrust forces acting on the rotor balance.

The bearing structure according to the present invention presents the following effects.

The bearing structure comprises magnetic bearings disposed so that thrust forces act in opposite axial directions, and a pivot displaced relative to a neutral position to bear a shaft end of the rotor, so that thrust forces act on the pivot in accordance with displacements from the neutral position to enable supporting in a quasi non-contact condition in the vicinity of the neutral position to thereby enable rotation in supporting condition with low friction and low noise over the entire speed range. Accordingly, the pivot bearing undergoes little friction and adequately stands super high speed rotation to generate no noises.

Further, rotation is effected in a non-contact condition in the radial direction to make effective a self-aligning action, which is greatly advantageous in self-correction of loss in dynamic balance to generate no vibration. Also, the bearing structure is made very simple to realize a bearing of high performance at low cost.

The provision of a stopper for limiting displacements of the rotor in the axial direction within a range of displacements where thrust forces born by the rotor are in the same direction enables stable thrust supporting even when the rotor moves in the axial direction.

At least one of supporting points for the rotor serves as a magnetic bearing of attraction type to enable obtaining a great radial supporting rigidity, thereby enabling making the bearing small-sized in construction, and the magnetic bearing of attraction type comprises stator side and moving side magnets provided by arranging in concentrical manner and spacing from each other two ring-shaped magnets magnetized in the axial direction with

directions of magnetization thereof opposite to each other, the both magnets being opposed to each other so as to attract each other in the axial direction, so that a closed magnetic path free from leakage of magnetic flux is formed to enable providing a great radial rigidity due to high density magnetic flux.

At least one of supporting points for the rotor serves as a magnetic bearing of repulsion type to enable ensuring freedom in constitution so as to insert the rotor from the bearing side in the axial direction for easy assembly of the rotor. In addition, the magnetic bearing of repulsion type comprises stator side and moving side magnets provided by arranging in linear manner and spacing from one another a plurality of ring-shaped magnets magnetized in the axial direction with directions of magnetization thereof being the same, the both magnets being opposed to each other so as to repel each other in the radial direction, so that a strong supporting force can be ensured simply by a batch polarizing treatment in a single process.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a longitudinal cross sectional view showing a bearing structure according to a first embodiment of the invention;

Fig. 2 is a cross sectional view showing an essential part of another constitution of the bearing structure shown in Fig. 1;

Fig. 3 is a cross sectional view showing an essential part of further constitution of the bearing structure shown in Fig. 2;

Fig. 4 is a longitudinal cross sectional view showing a bearing structure according to a second embodiment of the invention;

Fig. 5 is a cross sectional view showing an essential part of another constitution of the bearing structure shown in Fig. 4;

Fig. 6 is a cross sectional view showing an essential part of further constitution of the bearing structure shown in Fig. 5;

Fig. 7 is a longitudinal cross sectional view showing a bearing structure according to a third embodiment of the invention; and

Fig. 8 is a longitudinal cross sectional view showing a condition of displacements in the bearing structure.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 1 to 3 show a first embodiment of the present

invention, in which a radial magnetic bearing is of an axial attraction type. Figs. 4 to 6 show a second embodiment of the present invention, in which a radial magnetic bearing is of a radial repulsion type. Further, a stationary part, an armature or loads thereon (fan, polygon mirror and the like), which are to be inherently mounted on a stator and a rotor, are omitted in the accompanying drawings. Specific examples of the invention will be described below.

Fig. 1 is a longitudinal cross sectional view showing a bearing structure according to a first embodiment of the invention.

The bearing structure is an example which uses a radial magnetic bearing of axial attraction type, in which a rotor 1 is supported by magnetic bearings 3, 4 at two locations to be rotatable relative to a stator 2. A cylindrical-shaped moving side magnet 3a magnetized in an axial direction is fixed to one end of the rotor 1, and a cylindrical-shaped stator side magnet 3b similarly magnetized in the axial direction is fixed to the stator 2 to face the moving side magnet 3a with a gap G1 so that the moving side magnet 3a and the stator side magnet 3b attract each other to constitute the radial magnetic bearing 3.

Similarly, the radial magnetic bearing 4 is constituted by a moving side magnet 4a fixed to the other end of the rotor 1 and a stator side magnet 4b fixed to the stator 2 with a gap G2 (G2>G1) so that the moving side magnet and the stator side magnet attract each other. A pivot bearing 5 is constituted by a ball body 5a placed between a recess 5b, which is provided on an end surface of the rotor 1 to be concentrical with a rotating shaft 7, and

a pivot bearing portion 5c provided on a side of the stator 2. Further, a ring-shaped spacer 6 made of a non-magnetic material and having a thickness G3 (G3<G2) is mounted on an end surface of the stator side magnet 4b in the gap G2 of the radial magnetic bearing 4.

With such arrangement, the radial magnetic bearing 3 gives the rotor 1 a centripetal force in a radial direction and applies an attraction force F1 to the rotor 1 in a lefthand direction in a plane of the drawing. Similarly, the radial magnetic bearing 4 gives the rotor 1 a centripetal force in the radial direction and applies an attraction force F2 to the rotor in a righthand direction in a plane of the drawing. The forces F1 and F2 naturally depend upon the dimensions and magnetic characteristics of both the radial magnetic bearings 3 and 4, and also depend upon the respective gaps G1, G2 provided that such dimensions and magnetic characteristics are the same. With the arrangement, the gap G2 is greater than the gap G1, so that the force F1 exceeds the force F2, and a difference between the forces F1 and F2 is exerted on the pivot bearing 5. If the gap G2 approaches the gap G1, that is, in the vicinity of a neutral position where thrust forces balance, a force acting on the pivot bearing 5 approaches zero to enable realizing a quasi non-contact condition.

Also, in the case where a deadweight of the rotor itself or a steady-state external force F3 such as a reaction force caused by blast of a fan acts in the axial direction of the rotor 1, a vector sum (F1 + F2 + F3) of the forces F1, F2 and F3 can be optionally reduced by suitably setting the dimensions, magnetic characteristics and gaps, respectively, of the magnetic bearings 3 and 4.

The role of the spacer 6 will be described below. In the case of the quasi non-contact condition described above, but for the spacer 6 a slight thrust force from outside moves the rotor 1 rightward to present the relationship G2<G1, with the result that the moving side magnet 4a and the stator side magnet 4b attractingly stick to each other, and so the rotor 1 will not return to its original position even if the external force disappears. To cope with this, if the spacer 6 is provided as a stopper and a relationship (G1 + G2)<2G3 is established, then the rotor 1 will return to its original position even if a temporary external force acts and when the force disappears.

In addition, with a thin-type fan motor or the like, two-point supporting can be ensured by forming both the moving side magnets 3a, 4a integrally in the above-described arrangement and constituting three magnets in a set so as to generate supporting forces, respectively, at both ends of the integral moving side magnet, and a similar action is apparently effected. Thus, an explanation therefor is omitted.

Fig. 2 is a cross sectional view showing an essential part of another constitution of the bearing structure shown in Fig. 1. Similar parts to those in the above constitution will be designated hereinbelow by the same reference numerals. Thus, an explanation therefor is omitted.

In the above description, a single radial magnetic bearing comprises a single moving side magnet and a single stator side magnet, both of which are opposed to each other while the bearing structure shown in Fig. 2 comprises a moving side magnet and a stator side magnet, each of which

comprises a plurality of cylindrical-shaped magnets, to enable enhancing a radial rigidity.

Two moving side magnets 3a, 3aa are concentrically arranged on a back yoke 31 with directions of magnetization thereof opposite to each other, and similarly two stator side magnets 3b, 3bb are concentrically arranged on a back yoke 32 with directions of magnetization thereof opposite to each other. Magnetic flux generated by the magnets forms a loop free of leakage as shown by an arrow in the drawing to be high in magnetic flux density in the gaps, so that the radial rigidity increases higher than that expected by the provision of plural magnets.

Fig. 3 is a cross sectional view showing an essential part of further constitution of the bearing structure shown in Fig. 2.

The bearing structure comprises the moving side magnet 3a and the stator side magnet 3b, which are magnetized in the radial direction, to form a radial magnetic bearing of axial attraction type. With the arrangement, the object of the present invention can be attained as in the constitution described above, in which the radial magnetic bearing comprises magnets magnetized in the axial direction.

Fig. 4 is a longitudinal cross sectional view showing a bearing structure according to a second embodiment of the invention.

The bearing structure is constructed such that the cylindrical-shaped moving side magnet 3a magnetized in the axial direction is fixed to one end of the rotor 1, and the cylindrical-shaped stator side magnet 3b similarly

magnetized in the axial direction is concentrically fixed to the stator 2 with a gap so that the moving side magnet 3a and the stator side magnet 3b repel each other in the radial direction to constitute the radial magnetic bearing 3. Similarly, the radial magnetic bearing 4 comprises the moving side magnet 4a fixed to the other end of the rotor 1 and the stator side magnet 4b fixed to the stator 2.

Further, the moving side magnet 3a is disposed to be shifted a shift distance L1 lefthand relative to the stator side magnet 3b, and the moving side magnet 4a is disposed to be shifted a shift distance L2 (L2<L1) righthand relative to the stator side magnet 4b. In addition, the pivot bearing 5 comprises a pivot 5a, which is provided on an end surface of the rotor 1 to be cocentrical with the rotating shaft 7, and a pivot bearing portion 5c provided on a side of the stator 2. Further, a stopper surface 8 provided on the other end of the rotor 1 is spaced a gap L3 from a stopper surface 9 provided on the stator 2. However, the shift distances L1, L2 range in a predetermined limit, in which radial supporting forces are effectively obtained.

With the arrangement employing such radial magnetic bearing of radial repulsion type, the radial magnetic bearing 3 gives the rotor 1 a centripetal force in the radial direction and simultaneously applies a repulsive force F1 to the rotor in a lefthand direction in a plane of the drawing. Similarly, the radial magnetic bearing 4 gives the rotor 1 a centripetal force in the radial direction and simultaneously applies a repulsive force F2 to the rotor in a righthand direction in a plane of the drawing. The forces F1 and F2 naturally depend upon the dimensions and magnetic characteristics of both the radial magnetic bearings, and depend upon the shift distances L1,

L2 in the axial direction provided that such dimensions and magnetic characteristics are the same. With the arrangement, since L1<L2, the force F1 exceeds the force F2, and a difference between the forces F1 and F2 is exerted on the pivot bearing 5. If the shift distance L2 approaches the shift distance L1, that is, in the vicinity of a neutral position where thrust forces balance, a force acting on the pivot bearing 5 approaches zero to enable realizing a quasi non-contact condition.

Also, in the case where a deadweight of the rotor itself or a steady-state external force F3 such as a reaction force caused by blast of a fan acts in the axial direction of the rotor 1, a vector sum (F1 + F2 + F3) of the forces F1, F2 and F3 can be optionally reduced by suitably setting the dimensions, magnetic characteristics of and a positional relationship between the moving side magnet and the stator side magnet.

A gap L3 between the stopper surfaces 8 and 9 will be described below. While the stopper surfaces 8, 9 are provided to prevent the rotor 1 from separating from the stator 2, in the case of the quasi non-contact condition described above, a slight thrust force from outside moves the rotor 1 rightward to present the relationship L2<L1, with the result that the stopper surfaces 8, 9 contact with each other so that the rotor 1 will not return to its original position even if the external force disappears. To cope with this, if L3 is set to present (L1 - L2)<2L3, then the rotor 1 will return to its original position even if a temporary external force acts and when the force disappears.

Fig. 5 is a cross sectional view showing an essential

part of another constitution of the bearing structure shown in Fig. 4.

The bearing structure comprises two cylindrical-shaped moving side magnets 3a, 3aa, which are magnetized in the axial direction and provided on the rotor 1 with a spacing therebetween, and two cylindrical-shaped stator side magnets 3b, 3bb similarly provided on the stator. In this manner, being constituted by a plurality of cylindrical-shaped magnets, respectively, the bearing structure can be enhanced in radial rigidity due to great magnetic forces obtained from a simple magnetizing treatment in a single process, in contrast to the radial magnetic bearing described above, in which a single moving side magnet and a single stator side magnet are concentrically arranged.

Fig. 6 is a cross sectional view showing an essential part of further constitution of the bearing structure shown in Fig. 5.

The bearing structure comprises a radial magnetic bearing of radial repulsion type comprising the moving side magnet 3a and the stator side magnet 3b, which are magnetized in the radial direction. With the arrangement employing such magnets magnetized in the radial direction, the object of the invention can be attained as in the constitution described above, in which the radial magnetic bearing comprises magnets magnetized in the axial direction.

In addition, the above magnetic bearing of radial repulsion type can ensure freedom in constitution since it is possible to insert the rotor from the stator side for easy assembly of the rotor, by making an inner diameter on the stator side a dimension which exceeds the maximum

diameter of the rotor.

Fig. 7 is a longitudinal cross sectional view showing a bearing structure according to a third embodiment of the invention, and Fig. 8 is a longitudinal cross sectional view showing a condition of displacements in the bearing structure.

The bearing structure comprises, in place of the spacer in the bearing structure shown in Fig. 1, pivot bearings 5, 5 provided at both axial ends of the rotor 1, which supports a rotating mirror 11 and the like, to define a gap having a length L in an axial direction of the rotor 1.

The gap having a length L is made to have a dimension in a range capable of accommodating dimensional differences in assembly of respective constituent members and dimensional differences due to thermal expansions, and a neutral position where thrust forces produced by the magnetic bearings 3, 4 at two points balance each other is located substantially midway the gap.

With the above arrangement, either forces acting on the pivot bearings 5, 5 can be made infinitely or extremely small, so that a quasi non-contact condition can be realized and accuracy can be ensured for the structure in the axial direction of the rotor 1.

In the above description, two sets of radial bearings are of the same kind, but such matter is not at all necessary, and it goes without saying that a combination of optional kinds is possible.

The bearing structure according to the invention

presents the following effects.

The bearing structure comprises magnetic bearings disposed so that thrust forces act in opposite axial directions, and a pivot displaced relative to a neutral position to bear a shaft end of the rotor, so that thrust forces act on the pivot in accordance with displacements from the neutral position to enable supporting in a quasi non-contact condition in the vicinity of the neutral position to thereby enable rotation in supporting condition with low friction and low noise over the entire speed range. Accordingly, the pivot bearing undergoes little friction and adequately stands super high speed rotation to generate no noises.

Further, rotation is effected in a quasi non-contact condition in the radial direction to make effective a self-aligning action, which is greatly advantageous in self-correction of loss in dynamic balance to generate no vibration. Also, the bearing structure is made very simple to realize a bearing of high performance at low cost.

The provision of a stopper for limiting displacements of the rotor in the axial direction within a range of displacements where thrust forces born by the rotor are in the same direction enables stable thrust supporting even when the rotor moves in the axial direction.

At least one of supporting points for the rotor serves as a magnetic bearing of attraction type to enable obtaining a great radial supporting rigidity, thereby enabling making the bearing small-sized in structure, and the magnetic bearing of attraction type comprises stator side and moving side magnets provided by arranging in

concentrical manner and spacing from each other two ring-shaped magnets magnetized in the axial direction with directions of magnetization thereof opposite to each other, the both magnets being opposed to each other so as to attract each other in the axial direction, so that a closed magnetic path free from leakage of magnetic flux is formed to enable providing a great radial rigidity due to high density magnetic flux.

At least one of supporting points for the rotor serves as a magnetic bearing of repulsion type to enable ensuring freedom in constitution so as to insert the rotor from the bearing side in the axial direction for easy assembly of the rotor. In addition, the magnetic bearing of repulsion type comprises stator side and moving side magnets provided by arranging in linear manner and spacing from one another a plurality of ring-shaped magnets magnetized in the axial direction with directions of magnetization thereof being the same, the both magnets being opposed to each other so as to repel each other in the radial direction, so that a strong supporting force can be ensured simply by a batch polarizing treatment in a single process.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

WHAT IS CLAIMED IS:

1. A bearing structure comprising one or two sets of magnetic bearings for radially supporting a rotor of a rotating device at two supporting points in non-contact manner with magnetic forces, the magnetic bearings being arranged such that thrust forces thereof act in opposite axial directions, and a pivot disposed on an axis of the rotor for bearing a shaft end of the rotor at a point while displacing the shaft end in an axial direction from a neutral position where all thrust forces acting on the rotor balance.

2. The bearing structure according to claim 1, further comprising a stopper for limiting displacements of the rotor in the axial direction within a range of displacements where thrust forces born by the rotor are in the same direction.

3. The bearing structure according to claim 1, wherein at least one of said supporting points for the rotor serves as a magnetic bearing of attraction type.

4. The bearing structure according to claim 3, wherein said magnetic bearing of attraction type comprises stator side and moving side magnets provided by arranging in concentrical manner and spacing from each other two ring-shaped magnets magnetized in the axial direction with directions of magnetization thereof opposite to each other, the both magnets being opposed to each other so as to attract each other in the axial direction.

5. The bearing structure according to claim 1, wherein at least one of said supporting points for the rotor serves as

a magnetic bearing of repulsion type.

6. The bearing structure according to claim 5, wherein said magnetic bearing of repulsion type comprises stator side and moving side magnets provided by arranging in linear manner and spacing from one another a plurality of ring-shaped magnets magnetized in the axial direction with directions of magnetization thereof being the same, the both magnets being opposed to each other so as to repel each other in the radial direction.

7. The bearing structure according to claim 1, further comprising pivots provided at both ends of said rotor, and wherein a neutral position where all thrust forces balance is located substantially midway a gap in an axial direction of said rotor.

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|---|---|---|---|
| **Application No:** | GB 9904382.0 | **Examiner:** | John Hewet |
| **Claims searched:** | 1 to 7 | **Date of search:** | 12 May 1999 |

## Patents Act 1977
## Search Report under Section 17

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): F2A (AD10, AD14, AD16, AD18, AD19, AD36)

Int Cl (Ed.6): F16C 39/06

Other: Online: EPODOC, WPI, JAPIO

**Documents considered to be relevant:**

| Category | Identity of document and relevant passage | | Relevant to claims |
|---|---|---|---|
| X | GB 2134991 A | (BOSCH) see especially pivot 17 | 1, 2, 5 and 7 |
| X | GB 1481658 | (BALZERS) see especially page 2 lines 82 to 98, 113 to 122 and page 3 lines 24 to 35 | 1 to 3 and 7 |
| X | GB 739979 | (ROULEMENTS) see especially the figures and pivot 10 | 1 to 3 |

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |